

SCHILLINGER & * ADDISON

INTRODUCTION

This work was done to determine the feasibility of a new in-situ fusion method of applying rotating bands to projectiles. This concept (otherwise called Fused On Band) involves in-place melting and solidification of the band material, thus producing wetting and bonding of the material to the projectile wall. This process is differentiated from so called "cast on" bands by the fact that a metallurgical bond is achieved rather than a mechanical interlock.

The work consisted of experiments with several band materials and heating methods. Metallographic examinations were conducted on banded projectiles to determine the effects of the banding operation and subsequent heat treatment on the projectile's steel wall. In addition, a small scale firing test was conducted which demonstrated the effective functioning of projectiles banded by this method.

Traditionally, projectiles have been banded by swaging a ring of soft metal into a knurled and undercut seat which is cut into the projectile wall. One of the disadvantages of a band of this type is that it is liable, under certain circumstances, to be thrown from the projectile in firing. Thrown bands are undesirable because of the danger to friendly troops and equipment.

Additional disadvantages accrue to this type of band as attempts are made to design more modern projectiles with thinner walls, higher explosive to weight ratios, and higher velocities. In such design work, difficulty is encountered in achieving the design objective because of the necessity for the deep seat to withstand the forces induced by the swaging and firing operations. Thus, a web or a thickened wall must be used at the band position inside the projec-

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tile to provide sufficient strength. Also as higher velocities are sought, swaged bands tend to become more prone to malfunction.

Because of these various disadvantages of the swaged band, the more recently invented welded overlay rotating band has found favor for new generations of artillery projectiles. In this method of banding projectiles, a welded overlay is deposited on the outside of the projectile by the gas-metal arc-welding process. The overlay is bonded to the projectile wall and cannot come off if deposited correctly. Shallow band seats may be used if desired or the deposit can be applied to a perfectly straight wall. Various materials have been deposited in this way, including copper, gilding metal, aluminum bronzes and iron. After the overlay is deposited it is machined to band configuration by conventional machining techniques. Projectiles from 20mm to 280mm in diameter have been banded by this method.

Overlay banding also has certain disadvantages, however. Among these are that it is too slow at the current state-of-the-art to be a practical production method for banding small conventional projectiles. An additional disadvantage lies in the fact that the nonferrous overlay materials penetrate the austenitic grain boundaries of the steel shell being overlayed, thus introducing minute flaws into the wall of the shell being banded. These have demonstrable negative effects on shell wall strength for some steels and can introduce quench cracks in heat treating operations. The "fused on" band idea, therefore, was conceived in view of the desirability of producing an overlay type of band without some of its less desirable characteristics. In considering the new method, it appeared that the resulting band would be fully comparable with the overlay in terms of its strong bond and thus its applicability to thin walled shell. In addition to this similarity, however, the new method could have advantages over the overlay in that a greater savings in copper would be likely because of the ability to produce a configuration conforming more closely to the final band shape and dimensions. This would reduce scrap losses.

Also much higher application speeds seemed possible particularly with respect to small caliber projectiles if automated induction facilities or large furnaces could be suitably applied. A most significant possibility would be an improvement over the overlay process with respect to intergranular penetration. It was believed that the latter advantage could be expected because in the "fused on" band process the shell is heated all the way through, rather than just at the surface, as in the welding process. The significance of this difference is the fact that ferrous materials undergo a volume decrease due to lattice changes when heated into the austenitic range of temperature.

When the shell is heated all the way through, this simply results in a decrease in the volume occupied by the steel or, in effect, a density increase. However, if the heat affected zone does not penetrate the wall, a stress is established between the transformed and untransformed regions because of the volume differential. It is believed that this tensile stress exacerbates the problems of grain boundary penetration and cracking in the overlay process and that the occurrence of tensile stress would be precluded by the nature of the "fused on" band process.

This paper describes experimentation with the new method and the results obtained from the experimentation.

MATERIALS AND EQUIPMENT

Equipment employed in the experimentation described herein consisted mainly of a 20 kilowatt high frequency electronic tube type induction heater; and a tube furnace capable of temperatures in excess of 2000°F, with a three inch, stainless steel muffle and readily accessible fittings for adaptation to bottled gases. Standard metallographic facilities were employed for the metallography.

Materials used consisted of 30mm projectile bodies made of 4145 steel and the following materials in the form of shot made by cutting up welding wires:

Copper Development Association Alloy No. 189

Nominal Composition (Percent)

Cu	Sn	Si	Mn
98.75	0.75	0.3	0.20

Copper Development Association Alloy No. 240 (Low Brass)

Nominal Composition (Percent)

Cu	Zn
80.0	20.0

Copper Development Association Alloy No. 524 (Phosphor Bronze)

Nominal Composition (Percent)

Cu	Sn	P
90.0	10.0	Trace

The copper alloys cited above were not necessarily considered optimum materials for rotating bands or the process described in this report. They were used simply because they were readily available and are similar to materials presently used for rotating bands. Other compositions, particularly amongst the copper casting alloys, such as 90Cu-10Zn, might be preferable for the process or as rotating band materials depending on projectile requirements.

METHODS AND PROCEDURES

In this in-situ method of banding projectiles, a mold of graphite is prepared which fits closely around the bottom of the projectile. The mold has an appropriately sized cavity in the position where the band is desired. A refractory wash of zirconia flour is applied to the mold to prevent diffusion of carbon or other undesirable elements into the steel shell wall. The shell is then put into position and shot of the desired band composition is poured into the mold cavity. Figure 1 illustrates this arrangement. It is anticipated that a preform of the band material would perhaps be more satisfactory than shot, but in the experimental work, accomplished thus far, shot has been used because of the availability of the wire and the expense of machining preforms. However, in production, preforms could be made inexpensively using tubing cutoffs or some other easily formed blanks.

After the band material is added to the mold the entire assembly is heated in a non-oxidizing environment until the band alloy melts and bonds to the steel shell wall. Figure 2 shows a deposit being applied in an induction coil under an argon cover. The graphite mold shown provides a good susceptor for induction heating. Induction heating was employed almost exclusively in early experimentation although some initial experimentation was also done with furnace heating methods.

Another major variable in the experiments was band composition. Materials experimented with were as described in the Materials and Equipment section of this paper.

Shielding of the process is required to protect the graphite mold for reuse and avoid oxidation of the projectile wall which would otherwise prevent wetting of the steel. This too has been the subject of some of the experimentation performed thus far. Argon, proved to be a suitable shielding gas and was used throughout the work reported here.

When techniques of application were developed to the extent that suitable looking bands were formed, heat treating experiments were performed along with metallographic examinations to determine

SCHILLINGER & * ADDISON

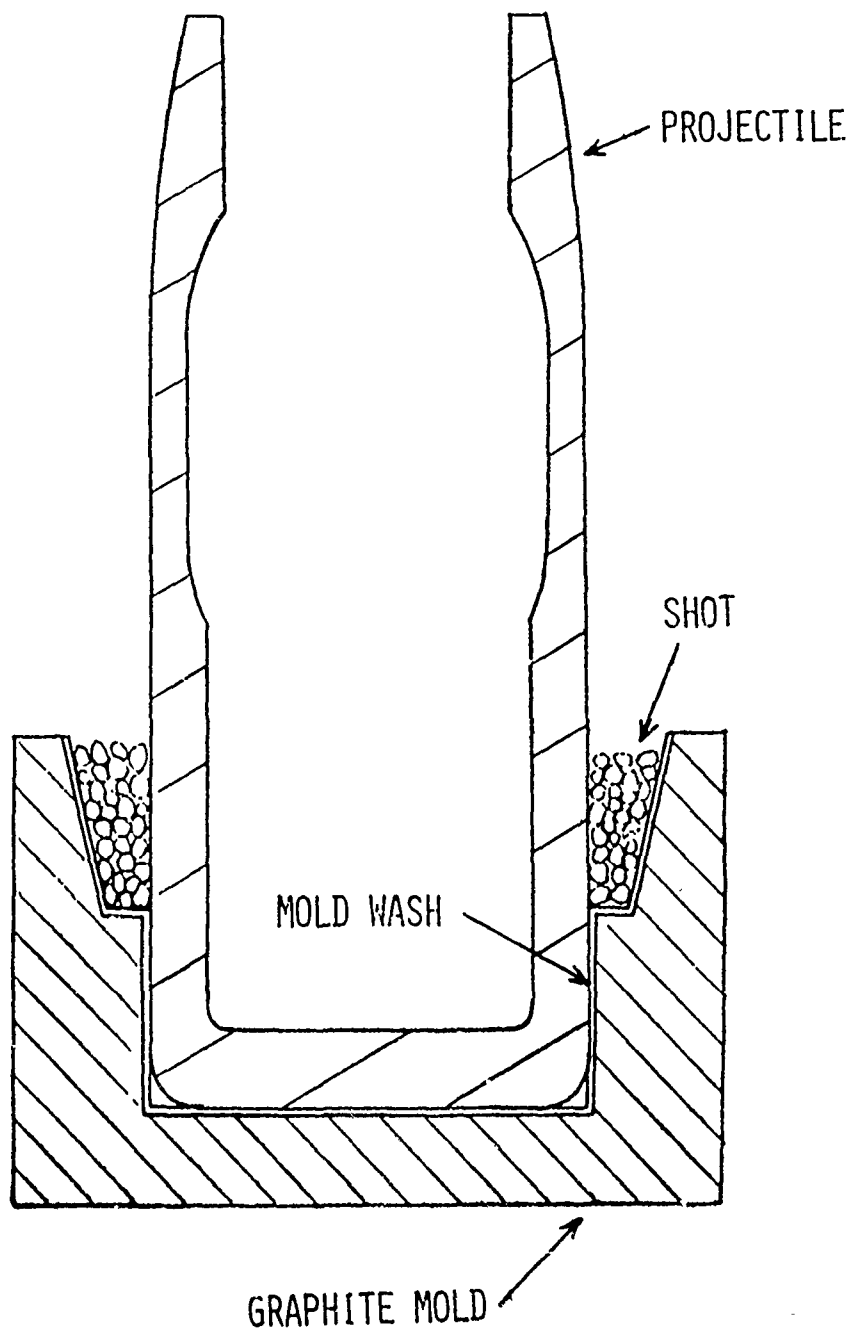


Figure 1. Schematic Showing Projectile Body, Mold and Shot Assembly Preparatory to Banding Operation

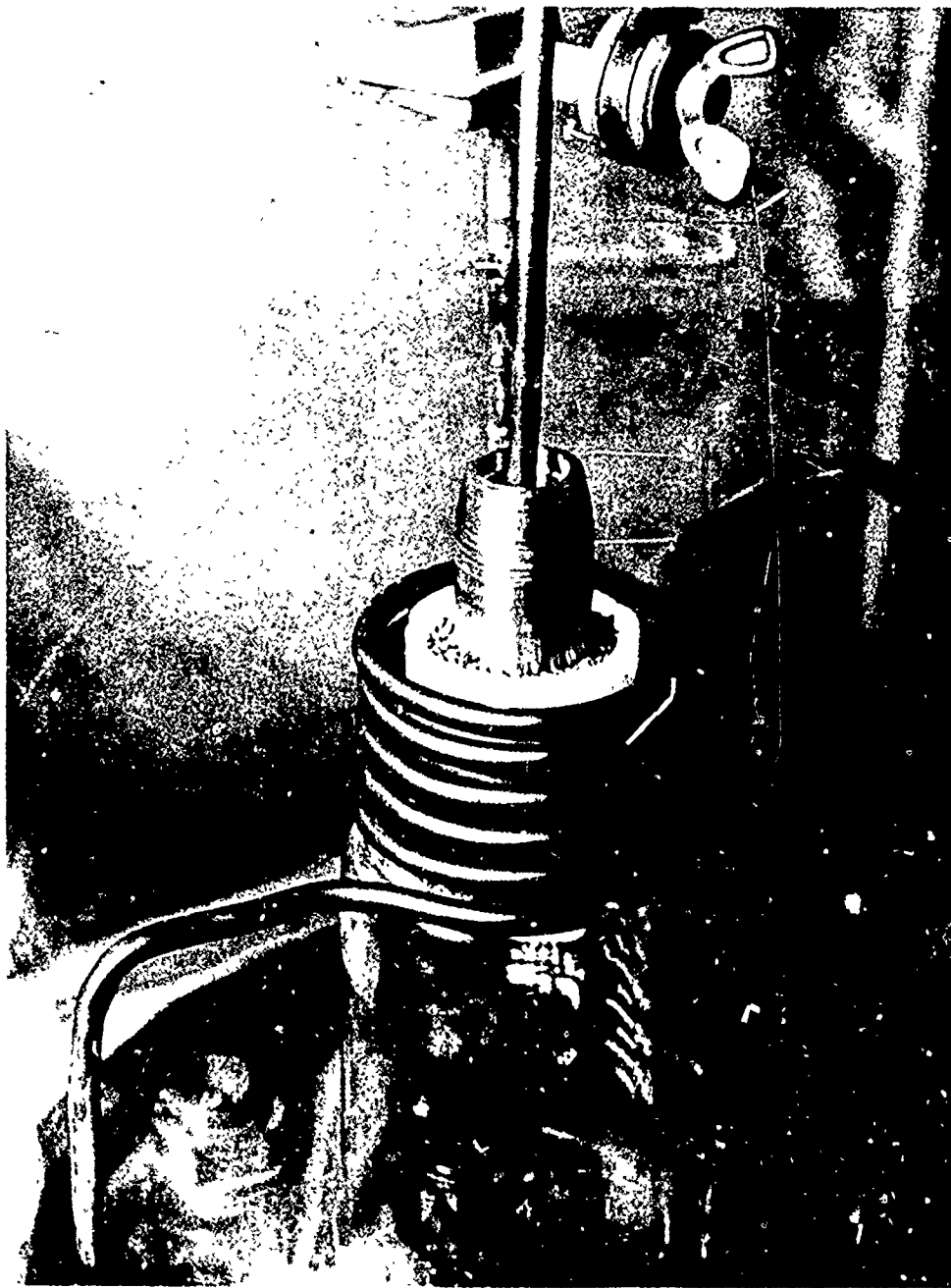


Figure 2. Induction Heating of Mold, Shot, and Projectile Body
Within Argon Filled Bell Jar

the quality of the deposit and whether undesirable structures produced in the steel body wall by the banding operation could be rectified by subsequent heat treatment.

In addition, a small scale firing test was conducted to determine if the applied bands would perform satisfactorily.

RESULTS AND DISCUSSION

Figure 3 shows three raw band deposits that were applied to 30mm projectiles under argon cover by induction heating. From left to right the bands are Copper Development Association Alloy 189, low brass, and phosphor bronze. After experimentation had reached the point where deposits of the quality shown in Figure 3 could be produced with regularity, specimens were metallographically examined to observe the interface, soundness of deposit and the effects of the process on the underlying steel.

Figure 4 shows a macrograph of a cross section of an induction fused copper (Alloy 189) band deposit. This shows that in wetting the steel, the alloy readily climbed the body wall forming a natural contact angle at the top of the band deposit. The quality of the band on a macroscale appears sound and the general configuration of the deposit is obvious.

The photomicrograph, Figure 5A shows at 100 magnifications, the interface produced between the 4145 steel projectile wall and the copper deposit. It may be seen that an excellent bond has been achieved. There is slight intergranular penetration of the prior austenitic grain boundaries, some decarburization at the steel surface and quite large grains (about ASTM 3) immediately below the deposit. The largeness of the grains is the result of grain growth which occurred at the high temperatures (approximately 2000 degrees) incurred in the banding process. It was determined, however, that this condition is corrected by subsequent heat treatment of the shell as shown in Figure 5B.

Good bonding was also obtained at the interfaces with low brass and phosphor bronze "fused on" bands. A metallographic survey showed little or no decarburization, good wetting and little intergranular penetration. However, the phosphor bronze deposits showed slight unsoundness.

In preceding portions of this paper it was pointed out that deposits were also applied to the projectiles using furnace methods. Figures 6 and 7 show, respectively, a copper (189 Alloy) furnace deposit and a cross section of such a deposit. While the deposit appears somewhat rough on the exterior due to external shrinkage

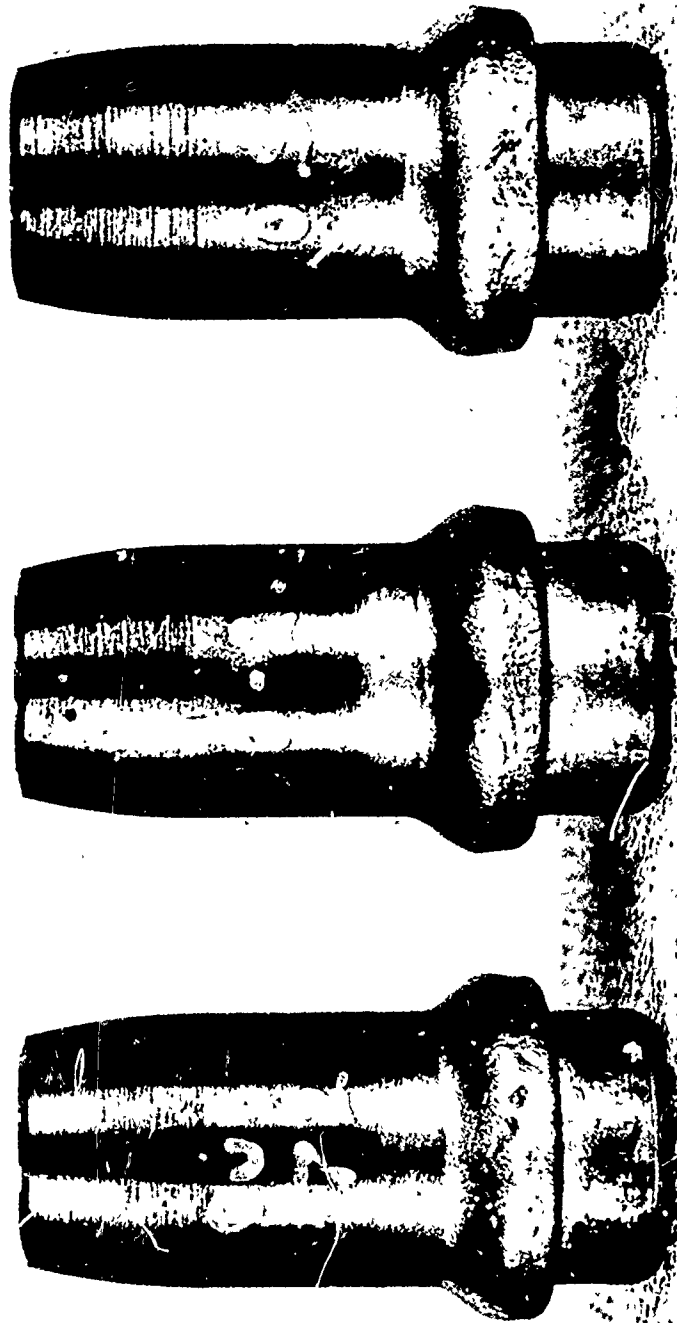
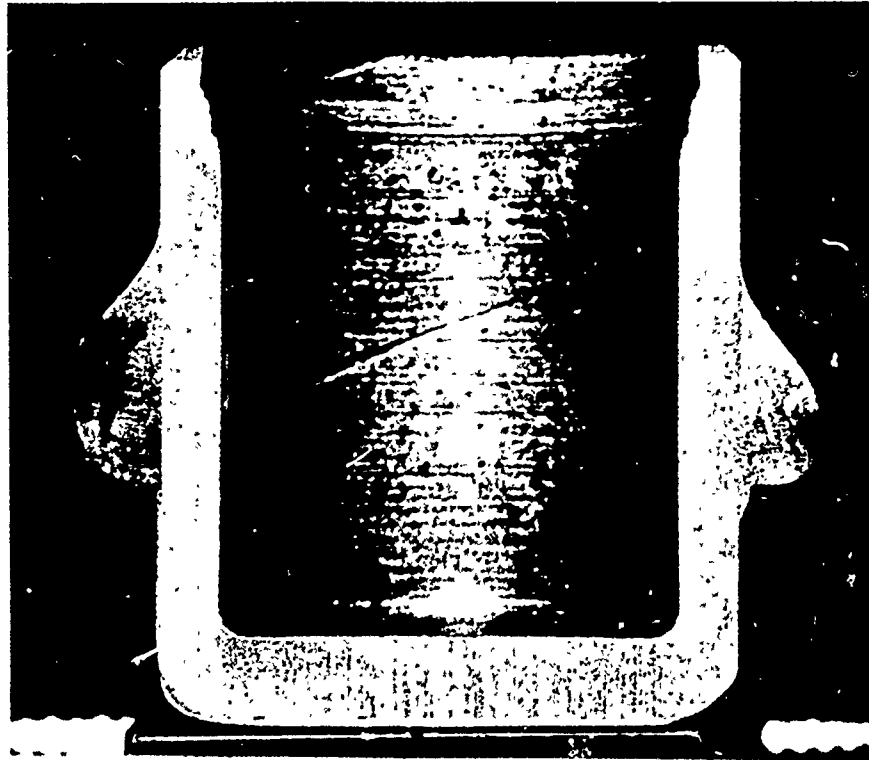


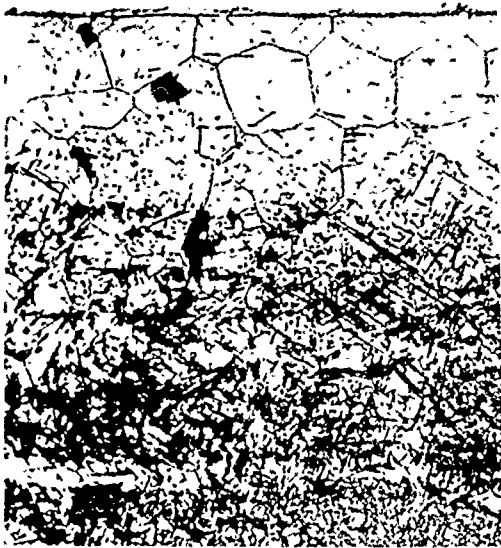
Figure 3. Induction Fused Band Deposits, Left to Right: Cu Alloy 189
Low Brass and Phosphor Bronze



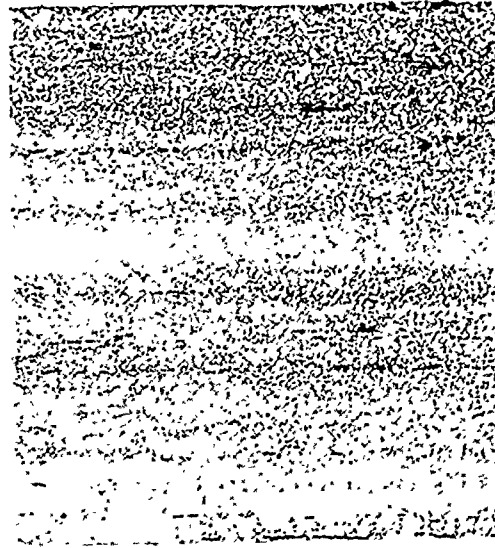
Etch: Steel; Nital Cu;
 NH_4OH , H_2O_2

Mag: 2-1/2 X

Figure 4. Section From 4145 Steel 30mm Projectile Body Showing Induction Fused Copper (Alloy 189) Band



A



B

Etch: Picral

Mag: 100 X

Figure 5. Interface and Microstructure in 4145 Steel Substrate; A: As Deposited, B: After Heat Treatment, Copper (Alloy 189) Deposit

SCHILLINGER & *ADDISON

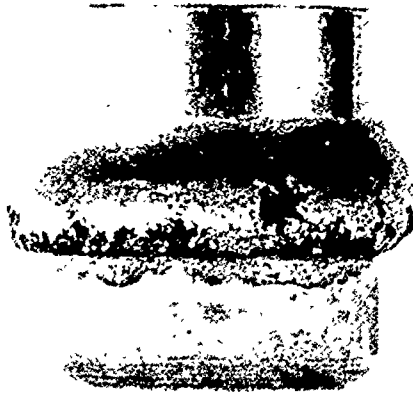


Figure 6. "Fused On" Band Deposit Made in Furnace with Argon Atmosphere; Copper (Alloy 189)



Figure 7. Cross Section of Fused On Band Deposit Made in Furnace with Argon Atmosphere; Copper (Alloy 189)

defects, the cross section shows that the deposit is sound and could be successfully machined into a rotating band.

Figure 8 shows the interface between the 4145 steel projectile and a 189 Alloy deposit. Again it can be seen that the bond is excellent but intergranular penetration and erosion are more severe than in the previously illustrated induction fused bands.

This is believed due primarily to excessive time in the furnace. (The specimen was put in for one hour with the furnace set at 2050°F.) Shorter times would probably reduce this erosion. However, the preliminary nature of this project did not permit adequate experimentation to determine appropriate furnace times.

For any given projectile or band material, this determination would probably require some degree of experimentation so that the assembly is not in the furnace any longer than is required to melt the band material. In the induction process, of course, it is possible to determine this by direct observation and erosion does not occur to any significant degree.

Having successfully demonstrated that deposits suitable for machining into rotating bands could be applied by this method it was decided to conduct a small scale firing test to verify whether or not the deposits would successfully function as rotating bands. Accordingly, several copper (Alloy 189) induction fused bands were applied to 30mm HEI T306 E10 projectile bodies. The bodies were then heat treated and the deposits and bodies were machined to the proper configuration for firing tests.

Three projectiles were fired at velocities between 2800 and 3000 feet per second. The results of these tests are illustrated in Figure 9. The two projectiles on the left were fired at chamber pressures of 70,000 pounds per square inch. The projectile on the right was fired at a chamber pressure of 90,000 pounds per square inch. It may be seen that the bands performed well. Of particular noteworthiness is the fact that even on the projectile which has fractured on impact (left projectile) all parts of the band remained attached to the steel.

CONCLUSIONS

(1) A new in-situ method for applying fused on rotating bands to projectiles has been demonstrated. U. S. Patent No. 3,888, 295 of 10 June 1975, has been granted on the method.

(2) The new method produces bands which are completely bonded to the projectile wall.

A



Etch: Picral

Mag: 100 X

Figure 8. Interface and Microstructure in 4145 Steel;
Furnace Deposited Copper (Alloy 189); As-
Deposited Condition

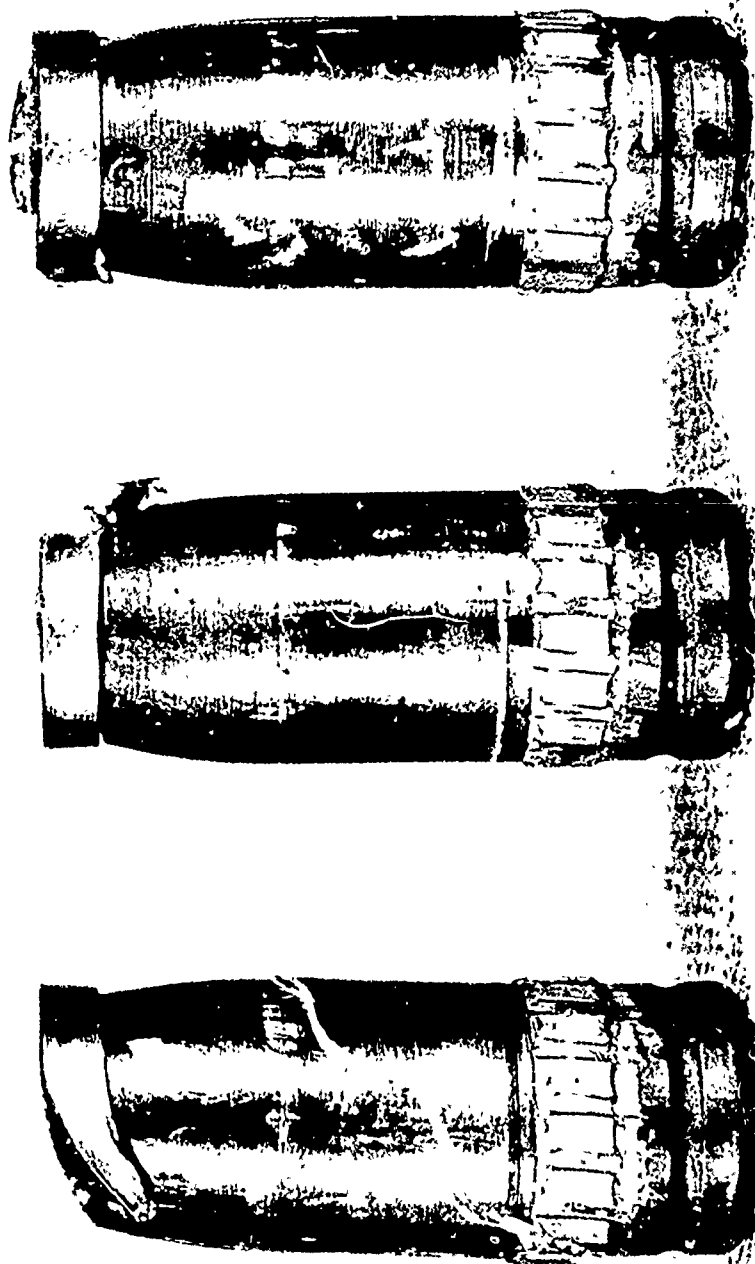


Figure 9. Fired 30mm HEI T306 E10 Projectiles Equipped with Induction Fused,
Copper (Alloy 189) Bands

(3) There is reason to believe that the new method produces less wall damage to the projectile than the gas metal-arc welded overlay process.

(4) It has been demonstrated that at least several copper alloys can be applied.

(5) It has also been demonstrated that copper alloy bands applied by the new method function successfully in firing tests.

RECOMMENDATIONS

It is recommended that additional study be given to this method to determine if the process can be refined to consistently produce high quality, high performance, nonferrous bands. Further attention should be given to the furnace banding method because of the possibility of obtaining higher production rates. Less expensive atmospheres than argon should also be sought. Some of the copper casting alloys should be studied as rotating band materials since these might not only prove more suitable for some applications because of higher strengths but also may be particularly suited to the process.

Support is currently being provided by the Army Materials and Mechanics Research Center to study these various aspects of the process.

If the method proves to be feasible as a production technique moderately large quantities of projectiles should be produced and test fired.

ACKNOWLEDGEMENT

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